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The effectiveness of the categories of protected areas in containing deforestation in the legal Amazon

A efetividade das categorias de áreas protegidas na contenção do desflorestamento na Amazônia Legal

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ABSTRACT

One of the greatest global threats to biodiversity is habitat loss. In the 20th century, deforestation increased in the tropical domain, the most biodiverse area on the planet. The main strategy in the protection of natural habitats has been the creation of protected areas. One of the ways to assess the effectiveness of protected areas is by monitoring the original coverage. This article aimed to compare deforestation between categories of protected areas and a sample of unprotected areas of Legal Amazon in 2017. It was found that 45.2% of the Legal Amazon territory is in protected areas: 23.0% in indigenous lands, 7.7% in full protection conservation units, and 14.5% in sustainable use conservation units. It was also verified that 20% of the forest areas of the Legal Amazon had been deforested until 2017. Statistical analyses of deforestation values led to the formation of two sets. Set 1, effective in containing deforestation: indigenous lands (11.4% deforested); full protection conservation units (16.9% deforested); sustainable use conservation units, category 1 - Sustainable Development Reserve, Extractive Reserve and Government Forest (10.4% deforested). Set 2, without effectivity in containing deforestation: sustainable use conservation units, category 2 - Environmental Protection Area, Area of Relevant Ecological Interest and Private Natural Heritage Reserve (35.8% deforested); Non-Protected Area (38.0% deforested). In the effective protection of biodiversity and ecosystem services in the Legal Amazon, it is recommended to create full protection conservation units. Alternately, sustainable use conservation units, category 1 (public lands), or indigenous territories should be created because they are essential for conserving the sociocultural diversity of the Amazon.

Keywords: Conservation Units, Environmental Preservation, Geoprocessing, Indigenous Territories, Tropical Forest.

RESUMO

Uma das maiores ameaças globais à biodiversidade é a perda de habitat. No século 20, o desmatamento aumentou no domínio tropical, a área de maior biodiversidade do planeta. A principal estratégia na proteção de habitats naturais tem sido a criação de áreas protegidas. Uma das formas de avaliar a eficácia das áreas protegidas é monitorando a cobertura original. Este artigo teve como objetivo comparar o desflorestamento entre categorias de unidades de conservação e uma amostra de área não-protegidas da Amazônia Legal em 2017. Constatou-se que 45,2% do território da Amazônia Legal estão em unidades de conservação: 22,9% em terras indígenas, 7,7% em unidades de conservação de proteção integral e 14,5% em unidades de conservação de uso sustentável. Também foi verificado que 20% das áreas florestais da Amazônia Legal haviam sido desmatadas até 2017. As análises estatísticas dos valores de desflorestamento levaram à formação de dois conjuntos. Conjunto 1, efetivo na contenção do desflorestamento: terras indígenas (11,4% desflorestada); unidades de conservação de proteção integral (16,9% desflorestada); unidades de conservação de uso sustentável categoria 1 - Reserva de Desenvolvimento Sustentável, Reserva Extrativista e Floresta do Governo (10,4% desflorestada). Conjunto 2, sem efetividade na contenção do desflorestamento: unidades de conservação de uso sustentável, categoria 2 - Área de Proteção Ambiental, Área de Relevante Interesse Ecológico e Reserva Particular do Patrimônio Natural (35,8%

desflorestada); Área Não Protegida (38,0% desflorestada). Na proteção efetiva da biodiversidade e dos serviços ecossistêmicos na Amazônia Legal, recomenda-se a criação de unidades de conservação de proteção integral. Alternativamente, devem ser criadas unidades de conservação de uso sustentável, categoria 1 (terras públicas) ou terras indígenas, por serem essenciais para a conservação da diversidade sociocultural da Amazônia.

Palavras-chave: Unidades de Conservação, Preservação Ambiental, Geoprocessamento, Territórios Indígenas, Floresta Tropical.

1. INTRODUCTION

One of the biggest global threats to biodiversity is habitat loss (SLINGENBERG *et al*., 2009; PIMM *et al*., 2014; DORŠNER, 2018). Until the end of the 19th century, the highest deforestation rates were in the planet's temperate regions. However, in the 20th century, deforestation increased in the tropical domain (FAO, 2016), the most biodiverse area on the planet (GIAM, 2017; DORŠNER, 2018), especially in developing countries (FAO, 2016). The Amazon rainforest has lost almost 20% of its original cover in the past 45 years (NOBRE *et al*., 2016). The forest loss in the tropics relates to wood extraction and expansion of areas occupied by agricultural activities and human settlements (SLINGENBERG *et al*., 2009; GIAM, 2017; DORŠNER, 2018). In the Brazilian Amazon, the main activity responsible for deforestation is livestock (RIVERO *et al*., 2009; FAO, 2016).

The Brazilian government has endeavored to contain deforestation advance in the Amazon, which has been more intense in the region denominated “arch of deforestation”, the eastern and southern margins of the Amazon (SKOLE; TUKER, 1993; ALVES, 2002; MARGULIS, 2004; FEARNSIDE, 2005; FERREIRA; VENTICINQUE; ALMEIDA, 2005; MARQUES *et al*., 2020; PEREIRA; FERREIRA, 2020), the transition zone between Cerrado and Amazon biomes. The conversion of native vegetation in the Cerrado/Amazon transition zone resulted in greater loss of unique habitats than in the savannahs of the Cerrado or the forests of the Amazon (MARQUES *et al*., 2020). The PRODES Project was created in 1988 for monitoring Amazon deforestation by clear-cutting (INPE, 2020). In 2004, the Brazilian government initiated the Action Plan for Prevention and Control of Deforestation in the Legal Amazon (PPCDAm). The most significant result of PPCDAm was a reduction in deforestation rate from 20,000 km² (period of 1996-2005) to 6,400 km², considering the average for 2014-2016 (BRASIL, 2018).

The main strategy for the conservation of natural habitats has been the creation of protected areas (BRUNER *et al*., 2001; OLIVEIRA *et al*., 2007; LEVERINGTON *et al*., 2010; GAVEAU *et al*., 2012; NOLTE *et al*., 2013; PIMM *et al*., 2014; FRANÇOSO *et al*., 2015; MELILLO *et al*., 2016). Presently, it is estimated that protected areas occupy about 13% of the planet's land surface (PIMM *et al*., 2014; MELILLO *et al*., 2016). In addition to being essential for biodiversity conservation, the protected areas play a key role in mitigating greenhouse gas emissions and maintaining environmental services, which are fundamental to human well-being (OLIVEIRA *et al*., 2007; LEVERINGTON *et al*., 2010; MELILLO *et al*., 2016).

In Brazil, the National System of Nature Conservation Units (SNUC) establishes the rules for creating, implanting, and managing conservation units (BRASIL, 2000). The conservation units (CUs) that integrate SNUC were defined according to the categories proposed by the International Union for the Conservation of Nature - IUCN (DUDLEY, 2008). Those are divided into two groups with specific characteristics: Fully Protected Conservation Units (FPCUs), whose objective is to preserve nature, with only the indirect use of its natural resources being allowed; and Sustainable Use Conservation Units (SUCUs), which seek to make nature conservation compatible with the sustainable use of a portion of its natural resources (BRASIL, 2000).

The FPCUs include the following categories: Ecological Station, Biological Reserve, Government Park, Wildlife Refuge, and Natural Monument. The SUCUs comprise the following categories: Sustainable Development Reserve, Extractive Reserve, Government Forest, Fauna Reserve, Environmental Protection Area, Area of Relevant Ecological Interest, and Private Reserve of Natural Heritage (BRASIL, 2000).

Considering only the continental part, 18.6% of the Brazilian territory (1,583,508 km²) is in some CU category: SUCUs (1,041,708 km²) represent 65.8% of the area; and FPCUs (541,800 km²) account for 34.2%. However, the areas of CUs are not evenly distributed among Brazilian biomes. About 76% of CUs area is in the Amazonia biome (1,203,007 km²), with the rest distributed among the other biomes (380,501 km² or 24%) (MMA, 2019).

Acknowledging that the protected areas play a fundamental role in the conservation of biological diversity, maintenance of environmental services, and sustainable use of natural resources, the Brazilian government created the National Plan for Protected Areas (PNAP), which in addition to the CUs, also included the indigenous territories (ITs) (BRASIL, 2006). The inclusion of ITs in PNAP was the recognition that, besides the importance for the life of the indigenous population, they contribute to biodiversity conservation and maintenance of environmental services, commitments described in the National Policy for Territorial and Environmental Management of Indigenous Territories - PNGATI (BAVARESCO; MENEZES, 2014). In Brazil, there are 720 ITs, occupying an area of 1,174,271 km², 13.8% of the country's land. Most of them (422) are in the Legal Amazon, covering 1,153,444 km², representing 23% of the Amazon territory and 98% of all ITs extension in the country (ISA, 2019).

The creation of protected areas (PA) as the pillar of the strategy for nature conservation only makes sense if these areas provide, in fact, protection for biodiversity, indigenous/traditional populations, and/or ecological services in the present and the future (BRUNER *et al*., 2001; LEVERINGTON *et al*., 2010; FRANÇOSO *et al*., 2015; MELILLO *et al*., 2016; DORŠNER, 2018). One way to assess the action of protected areas is by monitoring non-natural changes in the original coverage (FERREIRA; VENTICINQUE; ALMEIDA, 2005; OLIVEIRA *et al*., 2007; NAGENDRA, 2008; LEVERINGTON *et al*., 2010; GAVEAU *et al*., 2012; FRANÇOSO *et al*., 2015).

In general, protected areas have been shown to be effective in protecting natural environments since the conversion of original vegetation coverings for human use has been significantly less inside than in the surrounding unprotected areas (BRUNER *et al*., 2001; FERREIRA; VENTICINQUE; ALMEIDA, 2005; OLIVEIRA *et al*., 2007; NAGENDRA, 2008; LEVERINGTON *et al*., 2010; GAVEAU *et al*., 2012; NOLTE *et al*., 2013; FRANÇOSO *et al*., 2015). However, this method of assessing the role of protected areas should be used sparingly, since they are not randomly distributed in the territory (ANDAM *et al*., 2008; NAGENDRA, 2008; GAVEAU *et al*., 2012), and those located in the arch of deforestation are, in theory, under more deforestation pressure (NOLTE *et al*., 2013; PEREIRA; FERREIRA, 2020).

Based on the review, one can assess the effectiveness of protected areas in the Amazon in conserving natural environments, analyzing deforestation that occurs inside and outside them. For this purpose, this article aimed to compare the total percentage of deforestation in 2017 between categories of protected areas and also with a sample of non-protected areas in the Legal Amazon. To achieve the objective, the protected areas were organized into four groups, in addition to a sample of non-protected areas, resulting in five classes:

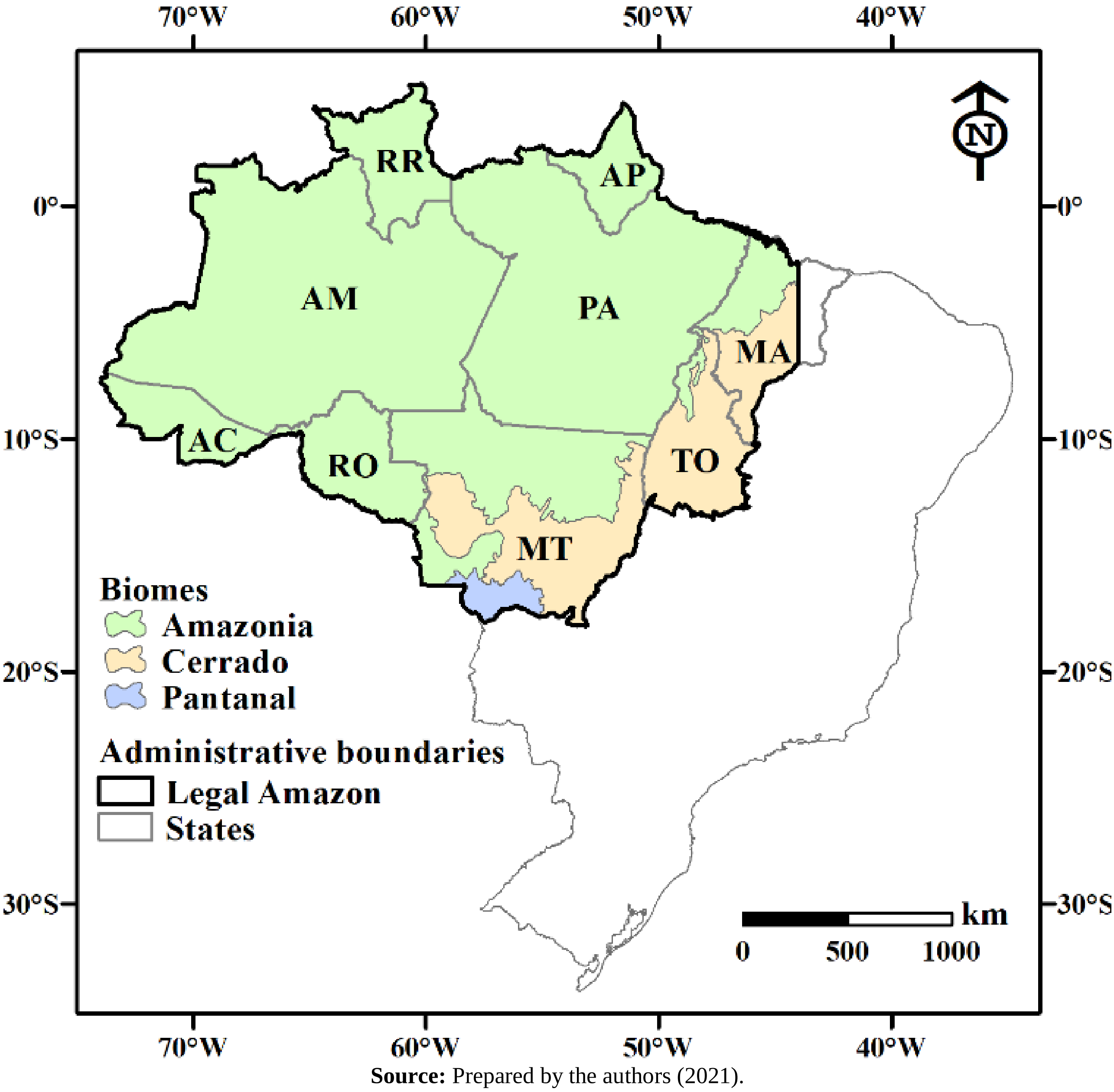
1. Indigenous Territories – IT;
2. Fully Protected Conservation Units – FP;
3. Sustainable Use Conservation Units - Category I - Public Domain (Sustainable Development Reserve, Extractive Reserve, and Government Forest) – SU1;
4. Sustainable Use Conservation Units - Category II - Private and/or Public Domain (Environmental Protection Area, Area of Relevant Ecological Interest and Private Reserve of Natural Heritage) – SU2;
5. Non-Protected Area – NPA.

2. MATERIALS AND METHODS

This study covered only the protected areas located in the Legal Amazon, an administrative region composed by the states of Amazonas (AM), Mato Grosso (MT), Pará (PA), Rondônia (RO), Acre (AC), Amapá (AP), Roraima (RR), Tocantins (TO), and municipalities of Maranhão (MA) located west of 44º meridian (**Figure 1**). It was created by Law 1,806 of January 6, 1953, resulting from the government's need to plan and promote the development of the Amazon region (SUDAM, 2020).

With an area of 5.015.067,749 km², the Legal Amazon represents about 58,9% of the Brazilian territory (IBGE, 2019). Although significant areas of the Cerrado biome occur in Tocantins, Maranhão, and Mato Grosso and a small area of the Pantanal biome in Mato Grosso, the Amazon biome is predominant in the Legal Amazon, representing 84% of the territory.

Figure 1: Legal Amazon



Source: Prepared by the authors (2021).

One of the first steps of this study was to obtain and organize geospatial data for protected areas (PA) from Legal Amazon, CUs (MMA, 2018), and ITs (FUNAI, 2018). The geospatial data were manipulated in the Geographic Information System (GIS) ArcGIS, version 10.0 (ESRI, 2005). The Albers projection, with the parameters defined by IBGE for the Legal Amazon (SANTOS; OLIVEIRA, 2003), was used to calculate areas.

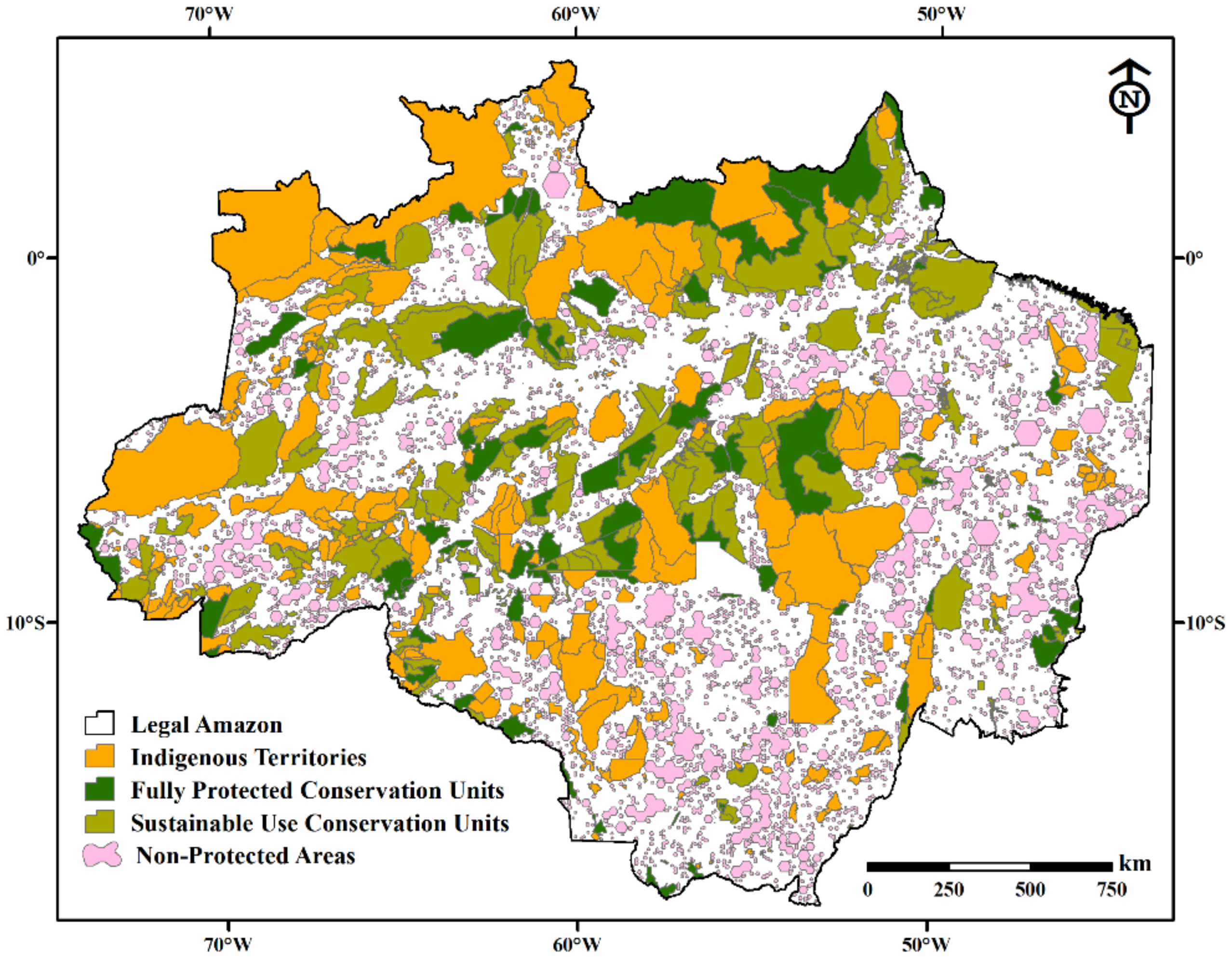
If the protected area extended beyond the limit of the Legal Amazon, only the area belonging to Legal Amazon was considered. In the organization of protected areas, the following order of priorities was adopted in case of overlap: 1 - IT; 2 - FP; 3 - SU. To remove all overlaps, it was necessary to convert the vector file (original format) to a raster format (**Figure 2**). The 30 by 30-

meter pixel was used as the standard spatial resolution, the same size as deforestation data for 2017.

To compare deforestation inside the protected areas with deforestation outside them, where only the new forest code is valid, that legislates on legal reserves and permanent protection areas (BRASIL, 2012), sampling was performed at the non-protected area (NPA).

In the sample definition, hexagonal areas of 500,000, 100,000, 50,000, 10,000 and 5,000 hectares were generated, being selected 20% from each size category with the aggregation of adjacent hexagons. Then, overlapping areas between classes of size were removed, with priorities for the larger, and, posteriorly, all classes of sizes were joined at the same layer. As the resultant layer was considered excessive, 35% of the areas were selected, resulting in a sample composed of 2664 polygons with dimensions from 5,000 to 1,200,000 hectares and corresponding to 21.9% of the NPA. Subsequently, the vector layer was converted to a raster format, with a resolution of 30 meters (**Figure 2**).

Figure 2: Protected areas and sample of a non-protected area in the Legal Amazon



Source: Prepared by the authors (2021).

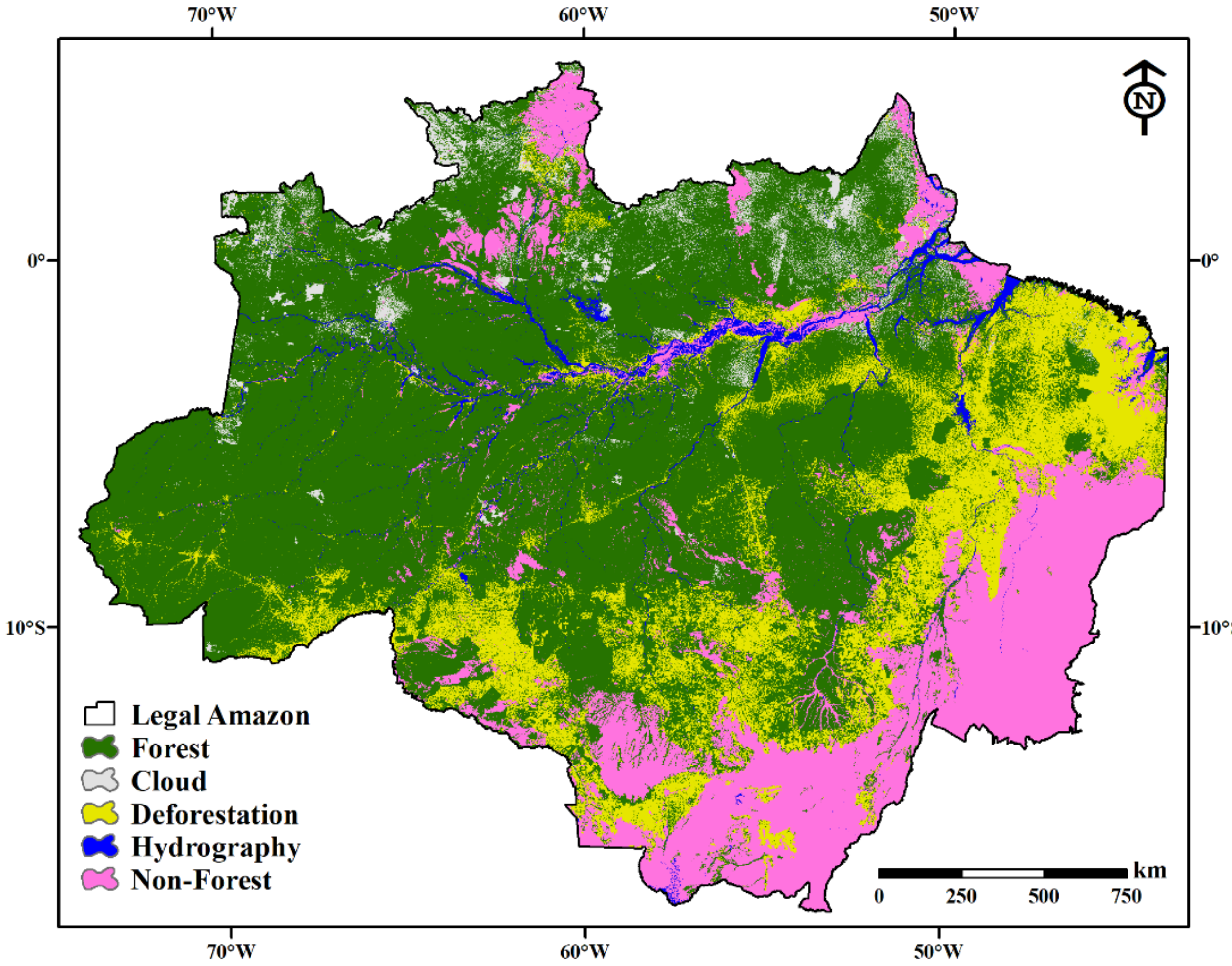
PRODES' deforestation data for 2017 (INPE, 2018) are organized into: eleven classes of deforestation (cumulative total until 2007 and annual deforestation until 2017); eight classes of residue, which is deforestation detected in a year in which it did not occur (residue from 2010 to 2017); two classes of non-forests (open vegetation formations like shrubland and grassland); forest (forest formations such as dense forest, open forest, and mangroves); hydrography (rivers and lakes); and cloud, which occurs exclusively over forests (INPE, 2018; 2020). As the interest was in cumulative deforestation until 2017, all classes of deforestation, including residue, were aggregated and the classes of non-forest, resulting in five classes: hydrography, non-forest, cloud, forest, and total deforestation by 2017 (**Figure 3**).

In order to obtain the total percentage of deforestation in 2017 for each protected area, a cross between PRODES data and protected areas was carried out. In the calculation of the total percentage deforestation (TotalDeforest%) of each protected area, the following **equation (1)** was used:

$$TotalDeforest\% = \frac{Total\ deforested\ area}{Forest\ area\ +\ Total\ deforested\ area} \times 100 \qquad \textbf{(1)}$$

Where:
Total deforested area = sum of annual deforestation and residue areas.
Forest area = sum of forest and cloud areas.

Figure 3: PRODES 2017, with aggregated classes



Source: Prepared by the authors (2021).

As percentage deforestation values of the classes did not present a normal distribution (Anderson-Darling test - $p < 0.005$, for all classes) or similar variances (Levene test - $p < 0.001$), which are basic premises for an analysis of variance (ANOVA), deforestation values were compared using the Kruskal-Wallis test, with a 95% confidence level (ZAR, 2010). The Minitab statistical package, version 15 (MINITAB, 2016), was used to perform Anderson-Darling and Levene tests and calculate the other statistics on deforestation values, while the Kruskal-Wallis test was applied using the Past statistical program, version 4 (HAMMER, 2021). The pairwise comparison of the deforestation values of the classes was performed using the Dunn test (PONTES; CORRENTE, 2001), also performed in the Past, with "p-value" being corrected for multiple comparisons.

3. RESULTS

After overlap removal, there was a 6.1% reduction in protected areas, with this percentage reduction being smaller in the ITs and greater in the FP categories. Although SU categories had a lower priority in removing overlapping areas, the percentage reduction in these categories was less than that of FP categories. These results demonstrated that ITs have greater overlap with FP than SU categories. With overlap elimination, it was found that 45.2% of the Legal Amazon territory was included in some category of the protected area, distributed as follows: 22.9% in ITs and 22.2% in CUs (FPs = 7.7% and SUs = 14.5%). Therefore, it was found that more than half of the protected area of the Legal Amazon is represented by ITs. The area of SU categories represents almost twice the area of FP categories. At the end of overlap removal, 719 protected areas remained (**Table 1**).

Table 1: Results of overlap removal and exclusion of protected areas without PRODES classes related to deforestation or less than 6.25 ha

Protected Areas	Original area (ha)	Original number	No overlap (ha)	No overlap number	Analyzed area (ha) [1]	No. analyzed areas	Final areas (%)	Final reduction (%)
ITs	115,932,601	383	115,105,770	383	113,831,610	364	51.0	1.8
FPs	45,926,770	112	38,732,968	109	37,106,868	93	16.6	19.2
SUs	79,529,130	228	72,939,540	227	72,433,104	212	32.4	8.9
Total	241,388,501	723	226,778,278	719	223,371,582	669	100.0	7.5

Source: Prepared by the authors (2021).

After the analysis of the cumulative deforestation in 2017, it was found that 47 protected areas (19 ITs and 28 CUs) could not be deforested, as they did not have areas related to the forest (forest/cloud and/or deforestation) mapped by PRODES. Therefore, they were excluded from the analysis. These protected areas were located basically in the Cerrado biome. As PRODES maps only areas above 6.25 ha, three other protected areas were also excluded because they had sizes below this value, all from SU categories. Thus, the universe of protected areas analyzed decreased from 723 to 669, which represented a reduction of 7.5% in the initial area (**Table 1**). As with the protected areas, some samples of NPA, located in the Cerrado biome, did not have PRODES classes related to the forest, being discarded. Consequently, the number of NPA samples decreased from 2664 to 2174, which represented a reduction of 18.4%.

Deforested areas represented 15.7% of the Legal Amazon in 2017 (**Table 2**). If only areas that can be effectively deforested are considered (disregard non-forest and hydrography), the deforested percentage increases to 20%. In this account, cloud areas have been added to forest areas. As in PRODES 2017 data, clouds were located exclusively over forests, and deforestation that occurred in the 2016-2017 period (727,748 ha or 7,277 km²), represented a reduction of only 0.2% of forest area. A small area under clouds may have been deforested. However, due to the importance of forest areas below clouds and the low percentage of deforestation, clouds were considered forests in this study.

[1] After removing protected areas smaller than 6.25 ha or without PRODES classes related to deforestation.

Table 2: Values of PRODES classes aggregated for Legal Amazon in 2017

Classes	Area (ha)	Area (%)
Forest	297,741,100	59.4
Non-forest	95,993,645	19.1
Hydrography	11,231,948	2.2
Cloud	17,752,058	3.5
Deforestation	78,802,997	15.7
Total	501,521,748	100.0

Source: Prepared by the authors (2021).

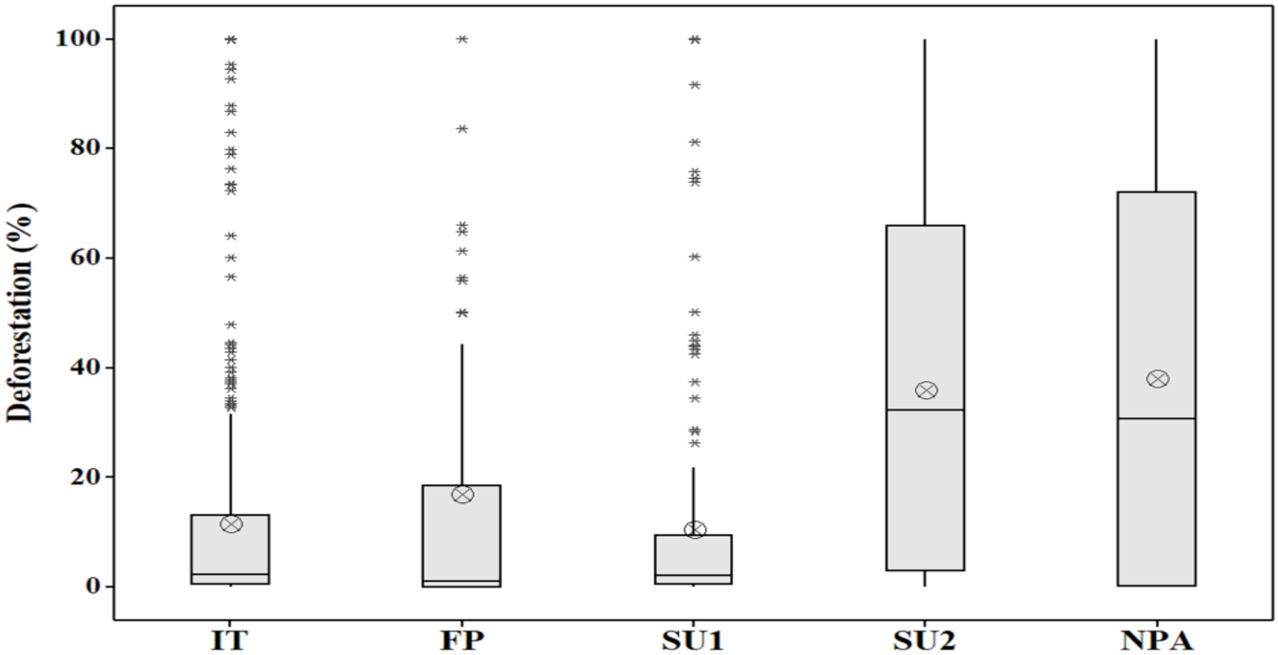
Except for SU1 class, which did not have zero deforestation, deforestation ranged from zero to 100% for all other classes (**Table 3**). The classes with higher average percentage values of deforestation were NPA and SU2, while SU1 and IT classes had lower ones. The average percentage of deforestation of the FP class was greater than SU1 (**Figure 4**).

Table 3: Percentage deforestation for the studied classes

Classes	No. of areas	Min.	Max.	Median	Average	Std. dev.	NPA/PA[2]	PA-NPA[3]
IT	364	0.00	100	2.35	11.4	20.52	3.3	-26.6
FP	93	0.00	100	1.06	16.9	30.14	2.2	-21.1
SU1	156	0.01	100	2.14	10.4	20.05	3.7	-27.6
SU2	56	0.00	100	32.21	35.8	32.77	1.1	-2.2
NPA	2174	0.00	100	30.69	38.0	36.04	1.0	0.0

Source: Prepared by the authors (2021).

Figure 4: Boxplot of percentage deforestation values for analyzed classes (circles represent the averages)



Source: Prepared by the authors (2021).

[2] Division of the percentage deforestation of the non-protected areas (NPA) by the percentage deforestation of the protected areas (PA).
[3] Subtraction of the percentage deforestation of the protected areas (PA) by the percentage deforestation of the non-protected areas (NPA).

This higher value of percentage deforestation of the FP group, in relation to the SU1 group, was due to totally deforested areas, small (up to 100 ha) and generally of municipal management, as are the cases of two municipal natural parks, “Botanical Garden” (89.6 ha) and “Sinop Forest Park” (105.8 ha), both in the center of Sinop, in the state of Mato Grosso. Possibly, these are small forest fragments that were neglected by PRODES data, and that due to their importance to the city, they were preserved, with a probable environmental restoration. Thus, they became natural parks. On the other hand, FP categories do not present any deforestation in the PRODES data, such as Rio Acre Ecological Station, in Assis Brasil (AC), and Xingu State Park, in Santa Cruz do Xingu (MT).

It was verified that, in at least one couple of comparisons, the classes analyzed have different deforestation values (Kruskal-Wallis test, $p < 0.001$). As the null hypothesis (equal deforestation values) was rejected, the groups were compared in pairs (Dunn's test). The pairwise comparison made it possible to verify the existence of two very distinct sets: (1) IT, FP, and SU1; (2) SU2 and NPA (**Figure 4**). There was a statistically significant difference in deforestation between groups of two sets ($p \leq 0.007$), which was not verified within each set ($p = 1{,}000$) (**Table 4**).

Table 4: Dunn's test: p-value from classes comparisons

	FP	**SU1**	**SU2**	**NPA**
IT	1.000	1.000	0.001	< 0.001
FP		1.000	0.007	< 0.001
SU1			0.001	< 0.001
SU2				1.000

Source: Prepared by the authors (2021).

This result makes it noticeably clear that US2 class (private and/or public domain), which included environmental protection area, area of relevant ecological interest, and private reserve of natural heritage, was ineffective in containing deforestation since deforestation was statistically different from other classes with protected areas (IT, FP, and SU1 which included sustainable development reserve, extractive reserve, and government forest). There was no statistical difference for the group that did not have any specific use restrictions (NPA), in addition to those provided for in the new forest code.

Comparing deforestation of groups that effectively took action against deforestation (IT, FP, and SU1) with deforestation of the group without use restriction (NPA), a reduction in deforestation was observed in groups of protected areas, from two (FP, 21.1% lower) to almost four times (IT and SU1, 26.6% and 27.6% lower, respectively), in relation to the area without restriction (NPA) (**Table 3**).

4. DISCUSSION

Some authors highlighted the role of protected areas in preserving natural areas, without distinguishing between categories (FERREIRA; VENTICINQUE; ALMEIDA, 2005; OLIVEIRA *et al*., 2007). Other authors highlighted the importance of the protected areas in the conservation of primary habitats; however, they did not find a significant difference between the protection provided by the FP categories when compared to SU categories (NAGENDRA, 2008; GAVEAU *et al*., 2012). On the other hand, some studies found that FP categories had been more effective than SU categories to avoid deforestation (NOLTE *et al*., 2013; FRANÇOSO *et al*., 2015).

A fact worth mentioning was the great difference in deforestation within protected areas when comparing the results obtained by Ferreira; Venticinque; Almeida (2005), using data from PRODES 2004, with those from this study that used data from PRODES 2017. Deforestation values recorded in protected areas by Ferreira; Venticinque; Almeida (2005) (1.5 to 4.7%) had one order of magnitude lower when compared to those obtained in this study (10.4 to 35.8%), which demonstrates that deforestation within Amazon protected areas has grown worryingly from 2004 to 2017 (13 years).

The present study results demonstrated the importance of ITs and FP categories in containing deforestation in the Legal Amazon. Concerning the role of SU categories, the results of this study were in an intermediate position between the results obtained by Nagendra (2008) and Gaveau *et al*. (2012) and those obtained by Françoso *et al*. (2015). In the case of the SU1 class, which included exclusively public domain categories (sustainable development reserve, extractive reserve, and government forest), there was efficiency in containing deforestation, corroborating what was observed by Nagendra (2008) and Gaveau *et al*. (2012). The Mamirauá Sustainable Development Reserve, located in the Amazonas state, represents a good example of CU from SU1 class, which effectively contains deforestation. The absence of deforestation in Mamirauá reserve (only 0.02%) is due, in large part, to exemplary community participation in its management (QUEIROZ, 2005). On the other hand, the SU2 class, which included categories of the public and private domain (environmental protection area, area of relevant ecological interest, and private reserve of natural heritage), was ineffective in containing deforestation, corroborating results of Françoso *et al*. (2015).

Nagendra (2008) suggests that in appropriate circumstances, local communities' involvement in the conservation of protected areas may provide options for more efficient monitoring and protection. The results of this study support this assumption by Nagendra (2008) since the SU1 class (public domain) demonstrated efficiency in containing deforestation, and by the example of Mamirauá reserve (QUEIROZ, 2005).

Differently, other authors question the effectiveness of SU categories in protecting natural environments. Gaveau *et al*. (2012) argued that logging increases vulnerability to fire, in addition to causing significant damage to forest regeneration and the vertebrate population. According to Nolte *et al*. (2013), the SU categories have higher percentages of deforestation when compared to FP categories because they are in places with more pressure for occupation. Françoso *et al*. (2015) stated that most SU categories have high costs associated with loss of biodiversity and environmental services.

In the Cerrado biome, governments have given priority to the creation of SU categories like environmental protection area or area of relevant ecological interest (SU2 class in this study), as they have low social, political, and economic costs since there is no expropriation and there are few restrictions on land use (FRANÇOSO *et al*., 2015). However, for the long-term conservation of natural environments in the tropics, with the effective protection of biodiversity and associated environmental services, studies have recommended the creation of FP categories such as ecological station, biological reserve, or government park (BRUNER *et al*., 2001; FERREIRA; VENTICINQUE; ALMEIDA, 2005; GAVEAU *et al*., 2012; FRANÇOSO *et al*., 2015). In addition to protecting nature, the creation of parks promotes ecological tourism, benefiting communities in the vicinity of the parks (BRUNER *et al*., 2001; FRANÇOSO *et al*., 2015).

5. CONCLUSION

This study evidenced the efficacy from Sustainable Use Conservation Units - Category I (Sustainable Development Reserve, Extractive Reserve and Government Forest) – SU1, Indigenous Territories – IT, and Fully Protected Conservation Units – FP in containing deforestation in the Amazon. They also demonstrate that Sustainable Use Conservation Units - Category II - Private and/or Public Domain (Environmental Protection Area, Area of Relevant Ecological Interest and Private Reserve of Natural Heritage) – SU2 were inefficient.

For effective protection of biodiversity and environmental services in the Legal Amazon, the creation of FP categories should be prioritized because these are the main purpose of these areas. However, if there is no government commitment to delimitation and enforcement, they will not be able to take decisive action in combating deforestation, as was seen in the increase in deforestation in protected areas from 2004 to 2017. Alternatively, even as observed in this study, the FP group showed deforestation higher than the SU1 group, although this difference was not statistically significant.

If it is not adequate to create a unit of FP category, the creation one of SU1 category (sustainable development reserve, extractive reserve, or government forest) or IT category should be stimulated. Even though the protection of biodiversity and environmental services may be questionable, these categories, besides having been effective in containing deforestation, are essential for conserving the sociocultural diversity of the Amazon.

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